

34 AMDT

ec'd PCT/PTO

15 MAR 2000

10/088240

10/088240

New specification part

(replace pp. 1 and 2 of the original specification)

# ELECTRONICALLY COMMUTATABLE MOTOR

## Background Information

5 The present invention relates to an electronically  
commutatable motor, whose excitation windings are  
controllable via semiconductor output stages by an  
electronic control unit with the aid of PWM control  
signals, a setpoint value being specifiable to the  
control unit, and the control unit emitting corresponding  
10 PWM control signals to the semiconductor output stages; a  
motor characteristic curve, from which an assigned  
nominal operating speed is derivable for the setpoint  
value, being stored in the control unit, and the derived  
nominal operating speed being able to be compared to the  
actual speed of the motor, and if a predefinable or  
15 predefined speed difference between the nominal operating  
speed and the actual speed is exceeded, the control unit  
and/or the semiconductor output stages is/are able to be  
switched off.

20 Such a motor is known from the German Patent  
195 04 874 A1. In that case, the PWM control signals are  
established in their pulse width by the input of the  
setpoint value. The comparison of the nominal operating  
speed, which is assigned to the setpoint value, to the  
25 actual speed is used during the continuous running

the characteristic curve changes as a function of the motor

94 AUG

load and the setpoint value, it requires a considerable expenditure of memory in the control unit to ascertain the allocated nominal operating speed for the comparison to the actual speed, i.e. for the monitoring of the motor.

To store the characteristic-curve data of a motor in a memory of the control unit and to use the characteristic-curve data for deriving an operating value is also known from the U.S. Patent 5,901,236 and from EP-A 0 386 057. In that case, as a rule, a characteristics field having a plurality of value pairs is used, from which the desired nominal operating value can be derived by interpolation onto a third coordinate. However, this requires a considerable expenditure of memory, particularly when the load of the motor also changes.

The object of the present invention is to provide a motor of the type mentioned at the outset with simple data in the control unit, which, with minimal expenditure, for a predefined load, significantly simplifies the derivation of the nominal operating speed corresponding to a predefined setpoint value.

This objective is achieved according to the present invention, in that the motor characteristic curve is stored as a characteristics field having four three-dimensional corner points; in the x-axis, the limiting values of the supply voltage, and in the z-axis, the limiting values of the PWM control signals determine

characteristics field permit the formation of a grid from

which, for an existing supply voltage and a PWM control signal corresponding to the predefined setpoint value, the allocated nominal operating speed is derivable for the comparison with the measured actual speed.

5

In this context, advantage is taken of the fact that in many cases, the motor is always loaded with the same consumer, such as in the case of a fan drive. The four....

10

15

20

25

30

sought nominal operating speed (in the y-direction).

Depending upon the use of the motor, according to a further embodiment, the four corner points of the characteristics field may be determined for a predefined motor load. The motor can then be designed in a simple manner for a different load, i.e. consumer.

In this context, according to one refinement, the comparison between the nominal operating speed and the actual speed is able to be carried out continually during the continuous running of the motor or repeated at time intervals.

The setpoint value may be specifiable manually in a simple manner using a potentiometer, the control unit being able to be supplied with a more or less large setting signal which is used for the emission of allocated PWM control signals for the semiconductor output stages. In addition, using this setting signal, the allocated nominal operating speed may be derived on the basis of the stored motor characteristic curve and utilized for the comparison with the actual speed of the motor arising. The actual speed of the motor may be detected in different ways which are also known.

For the comparison of the nominal operating speed and the actual speed, the control unit is preferably assigned a comparator unit which, by preference, is integrated into the control unit.

So that the speed of the motor can be controlled

semiconductor output stages to be switched off in a time-delayed manner.

If a run-up phase precedes the continuous operation of the motor, then the overload protection may be designed so that the comparison of the nominal operating speed and the actual speed is first able to be initiated and carried out after a run-up phase of a predefined duration has expired, so that an inadvertent shut-down does not occur during this operating phase. The run-up phase may be preset by the control unit, it being possible to use the amplitude of the pulses and the pulse width of the PWM control signals, as well as their commutation frequency and the like as parameters. The run-up phase of the motor is able to be initiated with the switch-on of the control unit and/or the semiconductor output stages, and/or the input of a setpoint value for the control unit.

The invention is explained more precisely with reference to an exemplary embodiment shown in the Drawing, in which:

Figure 1 shows a block diagram of the functional units of the motor; and

Figure 2 shows a characteristics field stored in the control unit.

As the block diagram according to Figure 1 shows, the motor unit includes an electronic control unit STE which is assigned a comparator unit VE. For a desired continuous operation, a correspondingly adjusted setpoint value  $N_{set, cont}$  is specified to this control unit STE.

where  $\mathbf{f}$  is a function from  $\mathbf{M}$  to  $\mathbf{M}$  satisfying the following property:  $\mathbf{f}$  takes every  $\mathbf{M}$ -satisfiable formula  $\phi$  to a formula  $\mathbf{f}(\phi)$

known manner and supplied as a signal to a comparator unit VE which may be integrated into control unit STE. Stored in control unit STE is a motor characteristic curve which allows the derivation of a nominal operating speed  $n_x$  for each setpoint value  $N_{setpoint}$ . This nominal operating speed  $n_x$  is obtained more or less exactly in the case of the predefined setpoint value  $N_{setpoint}$  if control unit STE, semiconductor output stages ESP and motor M are operating correctly, and no conditions exist which lead to a drop in actual speed  $N_{actual}$ .

Nominal operating speed  $n_x$ , like actual speed  $N_{actual}$ , is supplied to comparator unit VE, and a speed deviation  $\Delta N$  is ascertained. If actual speed  $N_{actual}$  is more than a predefined or predefinable speed deviation  $\Delta N$  below expected nominal operating speed  $n_x$ , then a fault exists which can lead to an overload during continuous operation. Therefore, comparator unit VE generates a switch-off signal AB with which control unit STE and/or semiconductor output stages EST can be switched off, as the contacts off in the electric circuit of supply voltage  $U_{batt}$  indicate.

If setpoint value  $N_{setpoint}$  is changed, then PWM control signals pwm, and therefore actual speed  $N_{actual}$  of motor M change, as well. A correspondingly new nominal operating speed  $n_x$  is supplied to comparator unit VE, and the comparison is carried out in the same manner for the new continuous operation with altered speed.

The switch-off of control unit STE and/or of

$N_{\text{setpoint}}$  and the existing magnitude of supply voltage  $u_x$ . The comparison by comparator unit VE may be carried out continually during the continuous operation, or repeated at time intervals. In addition, the overload protection by the comparison and the shutdown may first be switched to effective after reaching the nominal operating speed specified by the setpoint value, i.e. after a predefined or predefinable run-up time has expired. In this context, the run-up time may be started with the switching-on, that is to say, with the feeding of supply voltage  $u_x$  to control circuit STE and/or to semiconductor output stages EST, and/or with the application of a predefined setpoint value  $N_{\text{setpoint}}$  to control unit STE.

Nominal operating speed  $n_x$ , derived and calculated by control unit STE, is a function not only of existing supply voltage  $u_x$  with its limiting values  $u_1$  and  $u_2$ , but also of stored speeds  $n_{11}$ ,  $n_{12}$ ,  $n_{21}$ ,  $n_{22}$  of the corner points of characteristics field KF, as the specification  $n_x = f(N_{\text{setpoint}}, u_1, u_2, n_{11}, n_{12}, n_{21}, n_{22})$  in the Figure indicates, and as is clarified later.

As the three-dimensional characteristics field KF according to Figure 2 shows, the voltage range from  $U_{\text{max}}$  to  $U_{\text{min}}$  is plotted in the x-direction, while the pulse width from  $\text{pwm}_{\text{min}}$  to  $\text{pwm}_{\text{max}}$  extends in the z-direction. In the exemplary embodiment,  $U_{\text{max}} = 13\text{V}$  and  $U_{\text{min}} = 8\text{V}$  are selected, and the pulse width has a range from  $\text{pwm}_{\text{min}} = 60\%$  to  $\text{pwm}_{\text{max}} = 100\%$ . For the smallest supply voltage, given  $\text{pwm}_{\text{min}} = 60\%$  and  $\text{pwm}_{\text{max}} = 100\%$ , nominal operating speeds of  $n_{11} = 50 \text{ min}^{-1}$  and  $n_{21} = 1800 \text{ mm}^{-1}$

operating speeds  $n_{11}$  to  $n_{21}$  define the four corner points P1 to P4 in three-dimensional characteristics field KF.

and  $n_{11}$ ,  $n_{12}$  and  $n_{13}$ , and  $n_{21}$  and  $n_{22}$ , respectively, permit the formation of a grid which, for existing supply voltages  $U_x$  and pulse width  $pwm_x$  corresponding to a setpoint value, allows the derivation of allocated nominal operating speeds  $n_x$  on straight line  $n_{11} - n_{22}$ . Thus, given a supply voltage of  $U_x = 10.5V$  and a pulse width of approximately 87%, a nominal operating speed of approximately 1800  $min^{-1}$  can be interpolated from characteristics field KF.

This characteristics field KF is valid for a specific motor for a predefined, constant load. For another load, a characteristics field KF valid for it can be stored in control unit STE.

As the three-dimensional characteristics field KF according to Figure 2 shows, supply voltage  $u_x$  having the voltage range from smallest supply voltage  $u_1 = 8V$  to greatest supply voltage  $u_2 = 13V$  is plotted in the x-direction. In the z-direction, pulse width  $pwm$  of the PWM control signals is predefined, which may extend from minimal pulse width  $pwm_1 = 60\%$  to maximum pulse width  $pwm_2 = 100\%$ . Given a preselected load of the motor, four limit operation cases are ascertained with  $u_1$  and  $pwm_1$ ,  $u_1$  and  $pwm_2$ ,  $u_2$  and  $pwm_1$ , as well as  $u_2$  and  $pwm_2$ , which lead to nominal operating speeds  $n_x = n_{11}$ ,  $n_{12}$ ,  $n_{21}$  and  $n_{22}$ , and consequently define characteristics field KF according to Figure 2.

If motor M is loaded with a different load, then a similar characteristics field KF results having new

an exemplary embodiment shown in Figure 3.

$n_{12} = 150 \text{ min}^{-1}$  at  $u_2 = 13\text{V}$  and  $\text{pwm}_1 = 60 \%$

$n_{21} = 1800 \text{ min}^{-1}$  at  $u_1 = 8\text{V}$  and  $\text{pwm}_2 = 100 \%$

$n_{22} = 2900 \text{ min}^{-1}$  at  $u_2 = 13\text{V}$  and  $\text{pwm}_2 = 100 \%$

5 Characteristics field KF can be represented as a grid,  
the connecting lines between corner points  $n_{11}$  and  $n_{12}$ , and  
 $n_{21}$  and  $n_{22}$ , respectively, as well as  $n_{11}$  and  $n_{22}$ , and  $n_{12}$   
and  $n_{21}$ , respectively, specifying the gridding, and as is  
10 shown, for an existing supply voltage  $u_x$ , permitting the  
derivation of allocated nominal operating speed  $n_x$  in the  
case of existing PWM control signal  $p_x$ . PWM control signal  
 $\text{pwm}_x$  is allocated to predefined setpoint value  $N_{\text{setpointv}}$ .

15 As grid line  $nx_1 - nx_2$  shows, in the case of  $u_x = 10.5\text{V}$   
and a pulse width of  $\text{pwm}_x \approx 87.5\%$ , the derivation of  
nominal operating speed  $n_x$  leads to a value of  
approximately  $1800 \text{ min}^{-1}$ .

20 To calculate nominal operating speed  $n_x$  allocated to a  
setpoint value  $N_{\text{setpointv}}$ , one proceeds as follows:

$$\text{stg1} = \frac{n_{12} - n_{11}}{u_2 - u_1} \quad \text{stg2} = \frac{n_{22} - n_{21}}{u_2 - u_1}$$

25

$$n_{1x} = n_{11} + \text{stg1} * (u_x - u_1)$$
$$n_{2x} = n_{21} + \text{stg2} * (u_x - u_1)$$

$$n_x = n_{1x} + (n_{2x} - n_{1x}) * (N_{\text{setpointv}} - n_{1x}) / (n_{2x} - n_{1x})$$

Therein:

stg1 -

stg2 -

stgs3 -

5

$$n_v = n_{1v} + stg_3 * (pwm_v - pwm_1)$$

Since computer-internally, work is not done with the speed, but rather with its reciprocal value, the above equation for calculating surface point  $n_x$  must be changed around accordingly. With  $T_x = a/n_x$ , it follows that:

10

$$\frac{a}{T_x} = n_{1x} + stg_3 * (pwm_x - pwm_1)$$

$$T_v = \frac{a * (pwm_1 - pwm_2)}{\left( (stg_1 - stg_2) * u_v - n_{21} + n_{11} + (stg_2 - stg_1) * u_1 \right) * pwm_v + (pwm_1 * stg_2 - pwm_2 * stg_1) * u_v + pwm_1 * (n_{21} - u_1 * stg_2) + pwm_2 * (stg_1 * u$$

15

In the formula above, only supply voltage  $U_v$  and the pulse width of output stage control  $pwm_v$  are variable. The remaining factors may be stored as fixed parameters in the ROM or EEPROM. Following is once again the same formula with the variable names used in the program code.

20

$$v_{-IX} = \frac{K_{ZAEHL_1}}{\left( (K_{NENN_1} * v_{ubatt} + K_{NENN_2}) * v_{pwm\_endst} + K_{NENN_3} * v_{ubatt} + K_{NENN_4} \right)}$$

During the programming at the rear end of the assembly line, the corresponding parameters can now be transferred from the test stand into the EEPROM of the motor control

5

$$K_{NENN_1} = (stg_1 - stg_2)$$

$$K_{NENN_2} = -n_{21} + n_{11} + (stg_2 - stg_1) * u_1$$

$$K_{NENN_3} = (pwm_1 * stg_2 - pwm_2 * stg_1)$$

$$K_{NENN_4} = pwm_1 * (n_{21} - u_1 * stg_2) + pwm_2 * (stg_1 * u_1 - n_{11})$$